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Selection of eight-year-old Norway spruce (*Picea abies*(L.) karst.) plants in a progeny trial and mass production by cuttings

Utvalg av åtte år gamle granplanter i ett avkomforsøk og masseproduksjon av stiklinger

John Dietrichson
Christian Kierulf

Ås 1982

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Abstract

DIETRICHSON, J. & KIERULF, CHR., 1982. Selection of eight-year-old spruce (*Picea abies* (L.) Karst.) plants in a progeny trial and mass production by cuttings. (Utvalg av åtte år gamle granplanter i ett avkomforsøk og masseproduksjon av stiklinger). Medd. Nor. inst. skogforsk. *38*(1): 1—28.

Among the best families in a large eight-year-old progeny trial, plants were selected for vegetative mass propagation in 1969. Out of a group of 336 clones, the 20 with the highest rooting ability at age eight years were repropagated five more times from 1970 to 1977. Results from six propagation cycles are studied in two parts. The first involves estimation of variance components, heritabilities, and selection differentials. The genotypic value of each ortet is calculated as a sum of three effects due to: (1) the individual within the plot (2) the family within the stand (3) the stand within the provenance. The genotypic values of the ortets are correlated with the phenotypic mean values of the ramets, in each of the six propagation cycles. No significant correlations were apparent for height, shoot length and state of flushing.

The second part of the investigation concerns the stability of the clonal differences between propagation cycles. The repeatability between propagation cycles appears to be very low, and lower than was calculated between replicates for the same characteristics in the seedling trial.

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Utdrag

DIETRICHSON, J. & KIERULF, CHR. 1982. Selection of eight-year-old Norway spruce (*Picea abies* (L.) Karst.) plants in a progeny trial and mass production by cuttings. (Utvalg av åtte år gamle granplanter i ett avkomforsøk og masseproduksjon av stiklinger). Medd. Nor. inst. skogforsk. *38*(1): 1—28.

Blant de beste familiene i et stort åtte år gammelt avkomforsøk ble det valgt individer til vegetativ masseformering i 1969. Av et materiale på 336 kloner ble de 20 med høyest rotsetting ved åtte års alder formert ytterligere fem ganger i perioden fra 1970 til 1977. På denne måten er resultatene fra seks formeringsomganger blitt sammenliknet. Undersøkelsen omfatter to deler og den første er: Basert på varianskomponenter, arvbarheter og seleksjonsdifferensialene, er den genotypiske verdi til hver ortet beregnet som en sum av tre trinn. (1) Individet innen ruten (2) Familien innen bestandet (3) Bestandet innen proveniensen. Den genotypiske verdi for ortetene er blitt korrelert med de fenotypiske middelverdier for rametene — basert på de seks formeringsomgangene. Det forekommer ingen statistiske signifikante korrelasjoner for høyder, skuddlengder og tidlighet. Den andre delen av arbeidet konsentrerer seg om å undersøke stabiliteten av klonforskjellene mellom formeringsomgangene. Gjentakseffekten, basert på en formeringsomgang, viser seg å være meget lav, og lavere enn beregnet for de samme karakterene basert på et gjentak av det frøformerte forsøket.

Preface

In 1969 an eight-year-old short-term open pollinated progeny trial with Norway spruce (*Picea abies* (L.) Karst.) was about to be terminated at Follum Factory Experimental Farm, Hogsmark, Aas, Norway. The trial gave information on genetic variation between provenances, stand within provenances, and between different families within the stands. In addition there was also large variation between plants within the plots. In order to investigate if it would be possible to increase the gain any further than by selecting the best families within the best stand and provenance, it was decided to start this study on vegetative propagation of individuals.

Because the trial has run for a long time, many have participated. Technical assistant Tor Kvarme made the selections and did the propagation work in 1969 and 1970. Technical assistants Per Øien, Kittil Dyrud, Don Piggott, Frode Knutzen and Leif Kvarme participated in the different phases of the work such as propagation, planting and measurement. Mr. Tore Skrøppa helped during the discussion of the statistical analyses. Dr. Tony Shelbourne, Forest Research Institute, Rotorua, New Zealand, corrected the english manuscript. All of them are given our best thanks.

Ås-NLH, June 1982

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I. Introduction

Norway spruce (Picea abies (L.) Karst.) is an heterozygous naturally outcrossing species that is phenotypically variable in changing environments. A spruce forest of seedlings of a native provenance with its associated genetic and phenotypic variability should be particularly well protected against environmentally caused disasters.

Modern silviculture normally involve planting and strives for maximum volume production. Large phenotypic variation in these circumstances may well be a disadvantage.

Tree improvement is carried out with the object of increasing yield, and involves selection of parents, intercrossing, and progeny testing these, and production of improved seed in orchards. Genetic variability in the improved offspring is likely to remain large in spite of several generations of breeding.

Vegetative propagation is an alternative means of producing planting stock. Many species and varieties have been propagated vegetatively in horticulture for a very long time, but in forestry only a few species have been subjects for large scale clonal propagation. Of these could be mentioned *Populus sp., Salix sp., Eucalyptus sp., Cryptomeria japonica,* and *Chamaecyparis obtusa.*

Possible objectives in adopting vegetatively propagated planting stock in forestry are to reduce genetic variability, and to maximize genetic improvement by utilizing the total genetic variance, not just the additive portion of this, which is all that can be utilized in recurrent selection programmes and existing clonal seed orchards.

II. History

In Norway, trials of rooted cuttings were started in the 1950's. A large amount of work was done in selecting old trees of Norway spruce, but poor rooting and plagiotrophic growth soon after planting resulted. From 1959 onwards there was a change towards propagating younger trees, particularly from 9 to 11 year old progeny trials, and these showed after first propagation both high rooting ability and ultimately orthotropic growth, either immediately after rooting or some years later. RUDEN (1968) reported on genetic variation from such a clonal trial. His material, which included a total of 260 clones, was propagated in 1959, and planted in 1963 in four blocks at Hogsmark, near Aas. He showed large differences between clones in 17 characteristics at age 8, and 20 year results after propagation have been reported recently (SKRØPPA 1981).

Vegetative propagation of spruce was also investigated early in other countries e.g. in Canada by FARRAR (1942), and in West Germany by KLEINSCHMIT (1961). In these studies, the difficulties of propagating and growing ramets of older clones were documented. Later KLEINSCHMIT et al. (1973) proposed a new vegetative propagation programme for Lower Saxony in West Germany based on intensive selection of three to four-year-old seedlings in the nursery. This programme, which involved mass propagation of cuttings from the young ortets through repeated propagation cycles every three to four years, combined with testing of large numbers of the young clones, is still in operation, but has become more complicated than envisaged in 1973 (KLEINSCHMIT and SCHMIDT 1977). It is now apparent that ageing cannot be stopped entirely by repeated propagation, and the question arises as to how soon clones which were first selected at age three to four years must be rejected because of reduced growth rate, and an extended plagiotropic phase.

Similar programmes with vegetative propagation to produce planting stock have been initiated in Finland (LEPISTÖ 1977), Sweden (WERNER 1979, 1980; BENTZER 1981), and in Denmark (ROULUND 1976). In Norway, propagation trials of spruce with ortets selected at age four years were initiated in 1973. In 1981 the clones went through their third propagation cycle, so it will be some years before any final conclusion can be made. However, another earlier experiment, which form the subject of this report, promises to shed some immediate light on the problem of ageing, repeated propagation and interaction between clone and site.

III. Experimental material and methods

In 1966 a progeny and provenance experiment with 276 open pollinated progenies from 14 stands in Southern Norway, and five stands in Central Norway, was planted at Hogsmark, Aas, (Table 1). In addition 34 exotic provenances, mainly from bulk seedlots of many trees, from continental Europe and Finland were also planted. At planting, the seedlings were four years old. The trial followed a randomized block design with four replicates, sixteen plants per plot, and a spacing of 0.5 metres.

In 1968 all plots in the trial were measured for height, state of flushing (May 21/22), length of seventh year leading shoot, and prolepsis.

The results were reported by Dietrichson (1969, 71). On their basis the first and second best family from each of the 19 stands was selected. From each of the 38 families, and from each plot, two ortets were selected. In addition two provenances from Poland, and two from Czechoslovakia were selected as the best, and ortets were similarly selected from each of the 16 plots of these provenances. In September 1969, 35 cuttings were taken from each of the 336 ortets. The cuttings were taken from the third branch whorl from the top, downwards, and were set in a greenhouse in a sand and Sphagnum mixture at a temperature of approximately +20C and a relative humidity of 80—90 %. In January 1970 the rooted cuttings were root-pruned

Table 1. Geographic origin of 19 Norwegian stands which formed the basis for the selection of the cuttings. The next last column indicates the number of families which were tested in the trial. The last column gives the number of clones used in the propagation trials.
Den geografiske opprinnelsen til de 19 norske bestandene som dannet utgangspunkt for utvalget av stiklingene. Nest siste kolonne angir antall familier som ble testet i forsøket. Siste kolonne gir antall kloner anvendt i formeringsforsøkene.

Stand *Bestand*	Lat. N. *Breddegr. nord*	Long. E. *Lengdegr. øst*	Altitude m *H.o.h. m*	Number of families *Antall familier*	Number of clones *Antall kloner*
Senum	58°40'	7°46'	400	11	1
V. Slidre	61°06'	8°58'	390	7	—
Skasen	60°26'	12°19'	390	4	2
Bråstad	58°29'	8°42'	45	10	—
Seljord	59°27'	8°44'	120	22	—
Voss	60°35'	6°32'	400	12	—
Kviteseid	59°26'	8°22'	400	11	—
Bogstad	59°58'	10°38'	160	22	2
Onsøy	59°17'	10°51'	50	21	—
Sandar	59°12'	11°15'	50	21	1
Eidskog	60°01'	11°53'	400	6	2
Eina	60°31'	10°38'	400	16	—
Trysil	61°19'	12°15'	400	18	2
Aremark	59°09'	11°42'	130	13	—
Meråker	63°23'	11°43'	200	16	2
Meråker	63°21'	11°43'	400	24	—
Ogndal	64°02'	11°48'	200	5	4
Meldal	63°08'	9°51'	200	20	1
Meldal	63°04'	9°59'	400	17	2
Sum				276	19

and transplanted into small Jiffy-pots. The rooted cuttings were kept in the greenhouse until spring 1971.

In autumn 1970 cuttings were harvested from a sample of the same ortets from which cuttings were collected in 1969. A total of 48 ortets were selected from those which had given more than 90 % rooted cuttings. The objects of this second propagation were to identify good-rooting clones to base further propagation work on, and to produce as many cuttings of these clones as possible within the shortest possible time. The best 20 clones for further rooting were identified among those with the highest rooting in the 1970 collected clones (Table 1, gives the origin of the 19 Norwegian clones). The last clone is from a phenotypically outstanding seedling from Mähren, Czechoslovakia not listed in the Table. In spring 1971 the same 20 clones, from the 1969 propagation, were planted in rows, randomly, at 0.5 metres spacing,

at Hogsmark. In 1973 the same clones from the 1970 propagation were planted in the same way, adjacent to the 1969 propagation. This site is flat with poor air drainage and a clay soil.

In August 1974 several hundred new cuttings of each of the 20 clones were taken from the lower branches of the 1969 clonal trial, rooted in the greenhouse and planted in 1975 on a site 150 metres east of the 1969 and 1970 material. This site slopes gently southwards. The same completely random design with row plots was used as before.

In August 1977 50 cuttings from each clone were collected from the cuttings growing in each of the first three propagation cycle plantings, and were set in the greenhouse. All these cuttings were subsequently planted in 1978, in a block some 50 metres east of the 1974 material with a similar layout as before. This site also faces south, but the soil contains less clay than the 1969, 1970 and 1974 propagations.

The materials which are included in this study can be summarized as follows:

1 = cuttings taken from ortets in 1969
2 = cuttings taken from ortets in 1970
3 = cuttings taken from 1 in 1974
4 = cuttings taken from 1 in 1977
5 = cuttings taken from 2 in 1977
6 = cuttings taken from 3 in 1977

Fig. 1 illustrates the propagation cycles. The number of cuttings produced from each cycle was 25 to 50 per clone except for cycle No. 3, where it was more than 100; and the cuttings from the six categories have been grown at three different microsites within an area of 4 ha.

IV. Measurements and assessments

The following measurements and assessments have been made on these experiments.

1. Percentage of cuttings rooted at each stage — by clones
2. Plant heights (cm). Propagation cycle 1, 2, 3 — 1977. Propagation cycle 4, 5, 6 — 1980
3. Leading shoot length — all propagation cycles — 1981.
4. State of flushing — Propagation cycles 1, 2 — June 2, 1981. Propagation cycles 3, 4, 5, 6 — May 19, 1981
5. Leading shoot extension — measured on June 15, 16, 22 and July 10, and 31, 1981 — all propagation cycles

Both in 1979 and 1980 prolepsis was looked for, but since this occurred only on the Czechoslovakian clone, no record was made.

Approximately 30 ramets per clone per propagation cycle were measured for plant height and 10 ramets only for shoot extension and shoot length in 1981. The state of flushing according to LANGLET (1960) for each clone

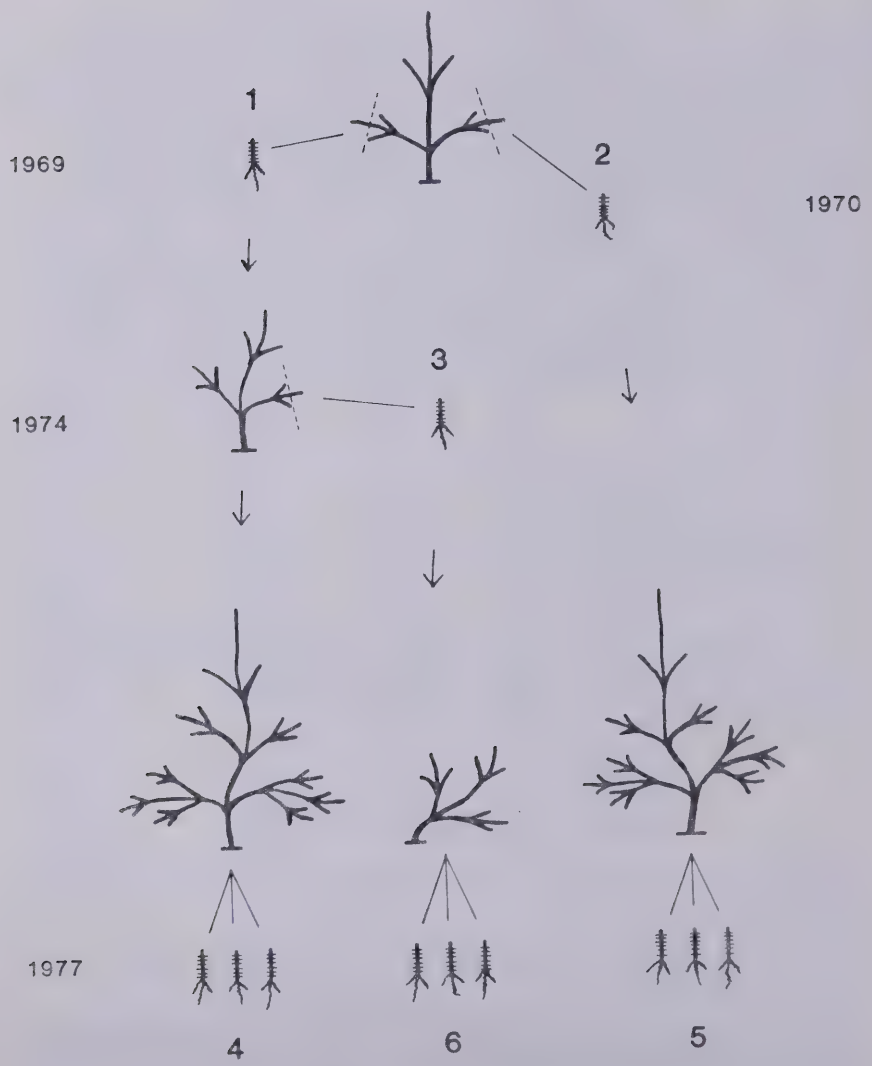

Fig. 1. Schematic illustration of the propagation cycles. 1 and 2 are cuttings taken from the ortets in 1969 and 1970. 3 are cuttings taken in 1974 from ramets produced in 1969 (1). 4 are cuttings taken in 1977 from ramets produced in 1969 (1). 5 are cuttings taken in 1977 from ramets produced in 1970 (2). 6 are cuttings taken in 1977 from ramets produced in 1974 (3).
Skjematisk illustrasjon av formeringsomgangene. 1 og 2 er stiklinger tatt fra ortetene i 1969 og 1970. 3 er stiklinger tatt i 1974 fra rameter produsert i 1969 (1). 4 er stiklinger tatt i 1977 fra rameter produsert i 1969 (1). 5 er stiklinger tatt i 1977 fra rameter produsert 1970 (2). 6 er stiklinger tatt i 1977 fra rameter produsert i 1974 (3).

within each propagation cycle was assessed as a single estimated average value for that row of ramets. There was almost no variation amongst the ramets of a clone row.

V. Analyses and calculations

The predicted genetic gain from selection of the ortets has been based on variance components estimated in an adjacent experiment with the same material in which the same characteristics were measured and assessed in 1968. Unlike the larger main trial, this one was balanced with 4 progenies from each of four stands in Central Norway, and 11 stands in Southern Norway, with 16 replicates of four-tree plots (DIETRICHSON 1969).

The genetic gain (G) from selection is the product of the selection differential (S), and the heritability (h^2) of the selection units (individual, family, and stand). Three selection differentials were calculated:

S_1 the differential between the selected individual and its plot mean
S_2 the differential between the selected family, and the mean of all families within that stand
S_3 the differential between the selected stand, and the mean of all the stands in that provenance

The stands from Central and Southern Norway were considered as two different provenances.

Furthermore three heritabilities have been calculated. The variance components used for these are:

σ_w^2 = within plot variance

$\sigma_{f:s}^2$ = family within stand variance

σ_s^2 = stand variance

$\sigma_{bf:s}^2$ = plot error

The heritabilities which refer to the three steps are:

$$h_1^2 = \frac{3\sigma_{f:s}^2}{\sigma_w^2}$$

$$h_2^2 = \frac{\sigma_{f:s}^2}{\frac{\sigma_w^2}{WB} + \frac{\sigma_{bf:s}^2}{B} + \sigma_{f:s}^2}$$

$$h_3^2 = \frac{\sigma_s^2}{\frac{\sigma_w^2}{WB} + \frac{\sigma_{bf:s}^2}{B} + \frac{\sigma_{f:s}^2}{C} + \sigma_s^2}$$

where W = number of plants per plot
B = number of replicates
C = number of families/stand, mean

Heritability No. 1 refers to the particular replicate and plot of a half sib family. But since σ^2_{fs} in the numerator has been derived from the differences between families within stands, and which relationship we really don't know, the calculating of h^2_1 is an approximation. For heritability No. 3, h^2_3, which refers to the stand, the error used in the denominator is also an approximation because of a variable number of families within stands.

Based on the three selection differentials and the three corresponding heritabilities, the genetic value for each ortet has been calculated as a sum of the genetic gain from each selection step, as follows:

$$G = X + S_1h_1^2 + S_2h_2^2 + S_3h_3^2$$

where $\overline{X}$ is the provenance mean.

The predicted genetic values for each ortet for height, state of flushing, and leading shoot length in 1968, were correlated with the clone means for the same characteristics in the six propagation cycles.

As a check the phenotypic values of each ortet were correlated with the clone means for the same characteristics in the six propagation cycles.

For the Czechoslovakian clone no correlations could be made, and only means are given.

It is important, if the purpose is to select and mass propagate cuttings without testing, that there is a good correlation between the genetic value of the ortets and the resulting ramets. Even without such a correlation however, it might still be possible to apply mass clonal propagation in forestry. The prerequisite for this must be that there are genetic differences between the clones in different traits, and that the rankings of clones for these are stable from one propagation cycle to the next. In order to provide answers to this question, two-way analyses of variance, with clone and propagation cycle as classifications, were made. The analyses based on clone means, and kept separate for each provenance have followed the model:

Source of variance	*Expectation, MS*
Clones	$\sigma^2_e + C\sigma^2_c$
Propagation cycles	$\sigma^2_e + K\sigma^2_{pc}$
Clones x propagation cycles	σ^2_e

Where C = number of propagation cycles
K = number of clones
σ^2_c = clonal variance
σ^2_{pc} = propagation cycle variance or the block variance
σ^2_e = experimental error

Because the cuttings from the six propagation cycles were planted at three different sites, and in spite of the fact that they were not separated by more than 200 m, the variance component for propagation cycles is confounded with that for sites.

In order to make the variance as even as possible between the propagation cycles, the data for heights were transformed to a logarithmic scale. This was not found necessary for data for the other characteristics. The other characters subjected to analyses were the leading shoot length in cm, the flushing score at June 2 for the propagation cycles 1 and 2, and at May 19 for the cycles 3, 4, 5, and 6. The analysis of variance for shoot extension was based on the percentage of shoot extended at June 15 for the cycles 1, 2, and 3, and June 16 for the cycles 4, 5, and 6. Per cent shoot extended was calculated by setting the shoot lengths at July 31 equal to 100.

On the basis of the variance components, the repeatability of the results from one propagation cycle to the next was calculated in the following manner:

$$\text{Repeatability} = \frac{\sigma_c^2}{\sigma_e^2 + \sigma_c^2}$$

For the Czechoslovakian clone analyses of variance could not be carried out and means only are given.

VI. Results

The heritabilities, and selection differentials for ortet selection within families, between families within stands, and between stands in provenances, are given in Tables 2, 3, and 4. The predicted genetic values for ortet height at age seven as well as leading shoot length, and flushing score, are plotted against the clone means of the ramets (Figs. 2, 3, and 4). None of the characteristics, kept separate for the two Norwegian provenances, show statistically significant correlations.

The same appeared to be the case when the phenotypic values for the ortets were plotted against the clone means of the ramets. The results of the two-way analyses of variance appear in Table 5. Propagation cycle variance σ_{pc}^2 is far larger than the clone variance σ_c^2 for both provenances. The nine central Norwegian clones show statistically significant differences only for plant heights. However, for the ten southern Norwegian clones there are significant clonal differences for heights, flushing score and shoot extension, though the variance between clones (σ_c^2) is small compared to the error variance (σ_e^2). This results in the heritability (h^2) for only one propagation cycle being very small. Expressed differently, the repeatability of the result from one propagation cycle to the next, is also very small. In Table 5, and for characters that show significant differences, the repeatability varies from 0.18 for height in the central Norwegian to 0.5 for earliness

Table 2. Heritabilities, h_1^2, h_2^2 and h_3^2 (according to the definition in the text) for selection within the family, stand, and provenance.
Arvbarhetstallene, h_1^2, h_2^2 og h_3^2 etter definisjonen i teksten, for utvalg innen familien, bestandet og proveniensen.

Characteristic *Karakter*	Central Norway provenance *Trøndelagsproveniens*			Southern Norway provenance *Østlandsproveniens*		
	h_1^2	h_2^2	h_3^2	h_1^2	h_2^2	h_3^2
Height *Høyde*	0.119	0.480	0.860	0.432	0.810	0.680
Leading shoot length *Toppskudd*	0.149	0.587	0.570	0.390	0.803	0.666
Flushing score *Tidlighet*	0.465	0.895	0.500	1.000*	0.935	0.800

* *Heritability above 1.000 reduced to one.*

Table 3. The selection differentials, S_1, S_2 and S_3 for the selected central Norwegian clones, and the provenance mean ($\bar{X}$) when seven-year-old (family, stand and provenance).
Seleksjonsdifferentialet, S_1, S_2 og S_3 for de utvalgte trønderklonene og proveniensmiddeltallet ($\bar{X}$) ved sju års alder (familie, bestand og provenjens).

Clone No. *Klon nr.*	Height, cm *Høyde, cm*				Leading shoot length, *Toppskudd cm*				Flushing score × 10 *Tidlighet × 10*			
	S_1	S_2	S_3	$\bar{X}$	S_1	S_2	S_3	$\bar{X}$	S_1	S_2	S_3	$\bar{X}$
60	+ 14	+ 1	— 1	53.6	+ 1	0	+ 1	20.6	— 1	— 3	— 1	27.5
89	+ 4	+ 1	— 1		+ 5	0	+ 1		— 6	— 1	— 1	
91	+ 8	+ 1	— 1		+ 7	0	+ 1		— 2	— 3	— 1	
102	+ 9	+ 5	— 2		+ 4	4	0		— 9	+ 3	0	
108	+ 7	+ 8	+ 1		+ 8	3	+ 1		— 3	— 1	0	
178	+ 15	+ 1	— 1		+ 10	0	+ 1		+ 4	— 1	— 1	
186	+ 23	+ 5	— 2		+ 10	4	0		+ 3	+ 3	0	
323	+ 19	+ 8	+ 2		— 1	— 1	— 1		+ 6	— 3	0	
324	+ 12	+ 8	+ 2		+ 10	— 1	— 1		+ 6	— 3	0	

performance in the southern Norwegian material. The variation between clones, and between propagation cycles is demonstrated in Figs. 5, 6, and 7 for clone means for rooting per cent, percentage height, and shoot extension per cent. These clone means are all percentages of the provenance mean over all the six cycles. Fig. 7 shows the shoot extension for the ten clones from Southern Norway separated for the six different propagation cycles. There appears to be a weak relationship between the shoot extension of the same clone in different propagation cycles, but the differences between the cycles are large.

Table 4. The selection differentials, S_1, S_2 and S_3 for the southern Norwegian clones, and the provenance mean ($\bar{X}$) when seven-year-old.
Seleksjonsdifferentialet. S_1, S_2 og S_3 for de utvalgte østlandsklonene og proveniensmiddeltallet ($\bar{X}$) ved sju års alder.

Clone No. *Klon nr.*	Height, cm *Høyde, cm*				Leading shoot length, *Toppskudd cm*				Flushing score × 10 *Tidlighet × 10*			
	S_1	S_2	S_3	$\bar{X}$	S_1	S_2	S_3	$\bar{X}$	S_1	S_2	S_3	$\bar{X}$
64	+ 13	+ 6	— 4	61.2	+ 4	+ 4	— 1	23.4	+ 10	— 3	— 3	27.0
123	+ 15	+ 2	+ 2		+ 4	+ 2	+ 1		+ 6	+ 9	+ 1	
164	+ 13	+ 2	+ 3		+ 7	— 2	+ 1		— 4	+ 5	— 7	
196	+ 9	+ 6	— 4		+ 7	+ 4	— 1		+ 19	— 3	— 3	
197	+ 37	+ 3	+ 2		+ 25	+ 1	+ 1		— 8	— 5	+ 1	
215	+ 19	+ 5	+ 2		+ 6	+ 1	+ 1		— 2	+ 1	— 1	
230	+ 10	+ 4	+ 3		+ 9	+ 3	+ 1		+ 4	+ 1	— 7	
253	+ 10	+ 5	0		+ 4	0	0		+ 3	— 6	+ 1	
254	+ 10	+ 5	0		+ 7	0	0		+ 23	— 6	+ 1	
334	+ 7	+ 6	0		+ 3	+ 4	+ 1		+ 17	— 5	+ 2	

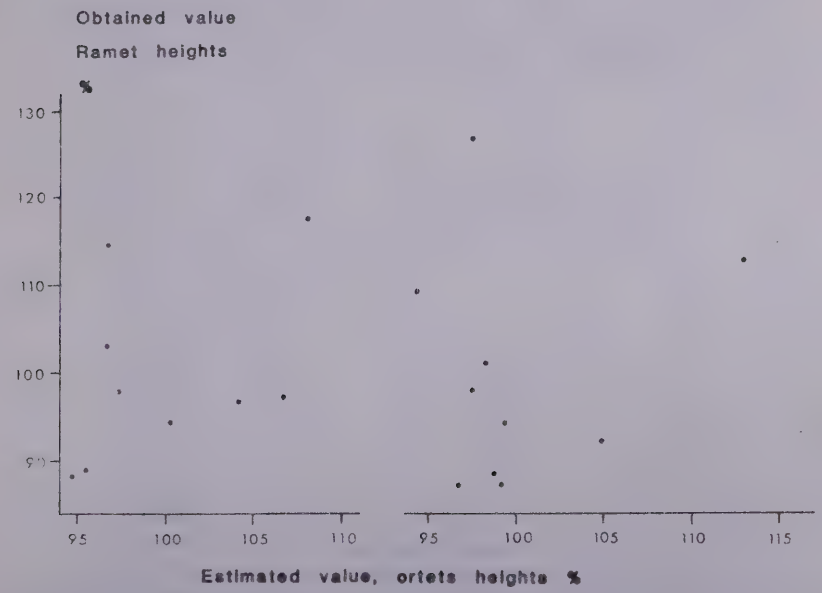

Fig. 2. The relationship between the estimated genetic value of the ortet heights, and the ramet heights. All values are in per cent of the overall mean. To the left are nine clones from Central Norway. To the right are ten clones from Southern Norway.
Forholdet mellom estimert genetisk verdi av ortet-høydene og ramet-høydene. Alle verdier er i prosent av forsøksgjennomsnittet. Til venstre er det ni kloner fra Midt-Norge. Til høyre er det 10 kloner fra Syd-Norge.

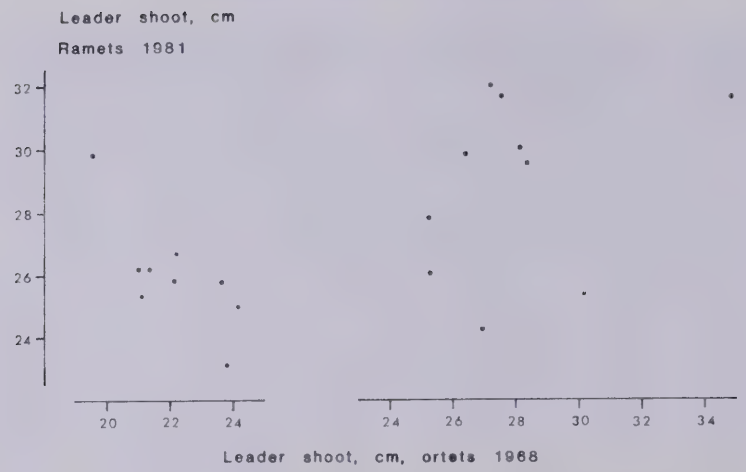

Fig. 3. The relationship between the estimated genotypic length of the leader shoot in the progeny trial in 1968, and the phenotypic mean for the same on the cuttings in 1981. To the left are the nine clones from Central Norway. To the right are ten clones from Southern Norway.
Forholdet mellom estimert genotypisk lengde av toppskuddet i avkomforsøket i 1968, og det fenotypiske gjennomsnitt for toppskuddet på stiklingene i 1981. Til venstre er det ni kloner fra Midt-Norge. Til høyre er det 10 kloner fra Syd-Norge.

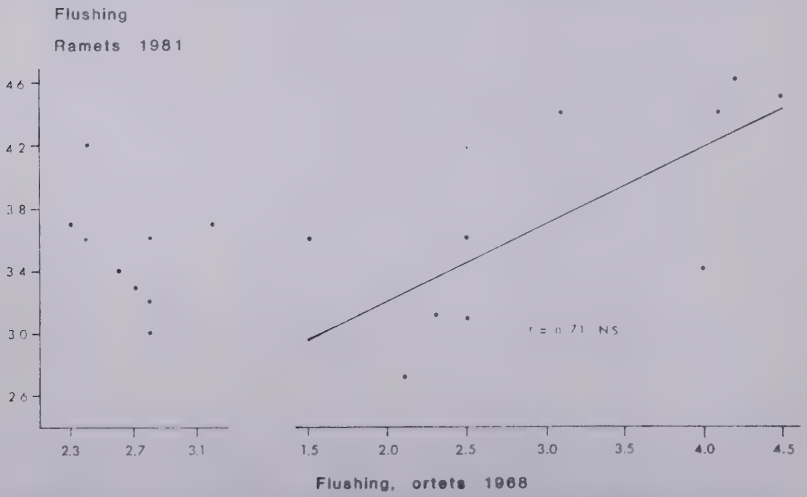

Fig. 4. The relationship between the estimated genotypic flushing performance in the progeny trial May 21, 22, 1968, and the phenotypic mean for the same on the cuttings in 1981. To the left are the nine clones from Central Norway. To the right are the ten clones from Southern Norway.
Forholdet mellom estimert genotypisk skuddskyting i avkomforsøket 21. og 22. mai 1968, og det fenotypiske gjennomsnitt for skuddskyting på stiklingene i 1981. Til venstre er det ni kloner fra Midt-Norge. Til høyre er det 10 kloner fra Syd-Norge.

Table 5. Variance components from analyses of variance of clones and propagation cycles.
Varianskomponentene fra variansanalysene av kloner og formeringsomganger.
σ^2_c = Clonal variance — *klon varians*
σ^2_{pc} = propagation cycle variance — *formeringsomgang varians*
σ^2_e = error — *feil*
h^2 = repeatability for one propagation cycle — *gjentaksevne for en formeringsomgang*

Characteristic *Karakter*	σ^2_c	σ^2_{pc}	σ^2_e	F-values clones *F-verdi*	DF	h^2
Central Norway — *Trøndelag*						
Height — *høyde*	0.0064	0.6623	0.0295	2.30*	8-40	0.18
Leading shoot length — *toppskudd*	— 1.0000	72.0000	26.0000	0.73	8-40	0.00
Flushing score — *tidlighet*	0.0350	0.2600	0.4700	1.47	8-40	0.07
Shoot extension — *skuddstrekning*	7.8300	538.8000	54.0000	1.90	8-40	0.13
Southern Norway — *Østlandet*						
Height — *høyde*	0.0071	0.6324	0.0159	3.67**	9-45	0.31
Leading shoot length — *toppskudd*	2.0000	70.0000	37.0000	1.27	9-45	0.05
Flushing score — *tidlighet*	0.4310	0.2160	0.4340	6.96**	9-45	0.50
Shoot extension — *skuddstrekning*	15.8300	262.0000	52.0000	2.83*	9-45	0.23

* Significant at the 5 % level
** Significant at the 1 % level

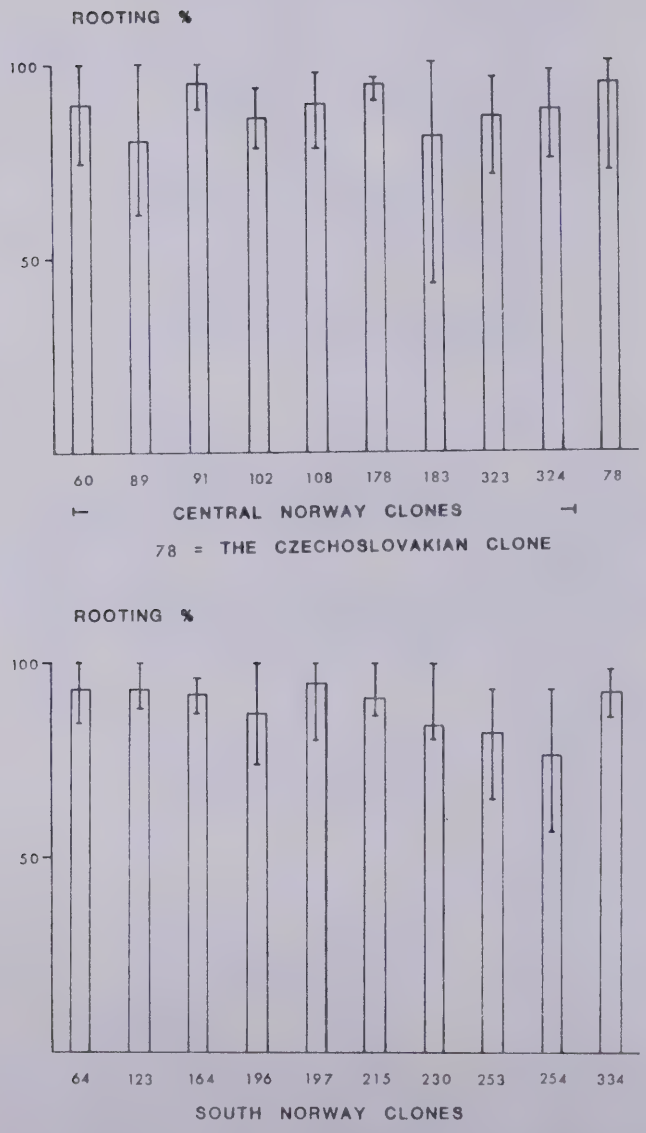

Fig. 5. The average rooting per cent for 20 clones, and six propagation cycles. The central vertical line indicate the largest, and smallest value.
Den gjennomsnittlige rotsettingsprosenten for 20 kloner og seks formeringsomganger. Den sentrale vertikale linjen angir den største og minste verdien.

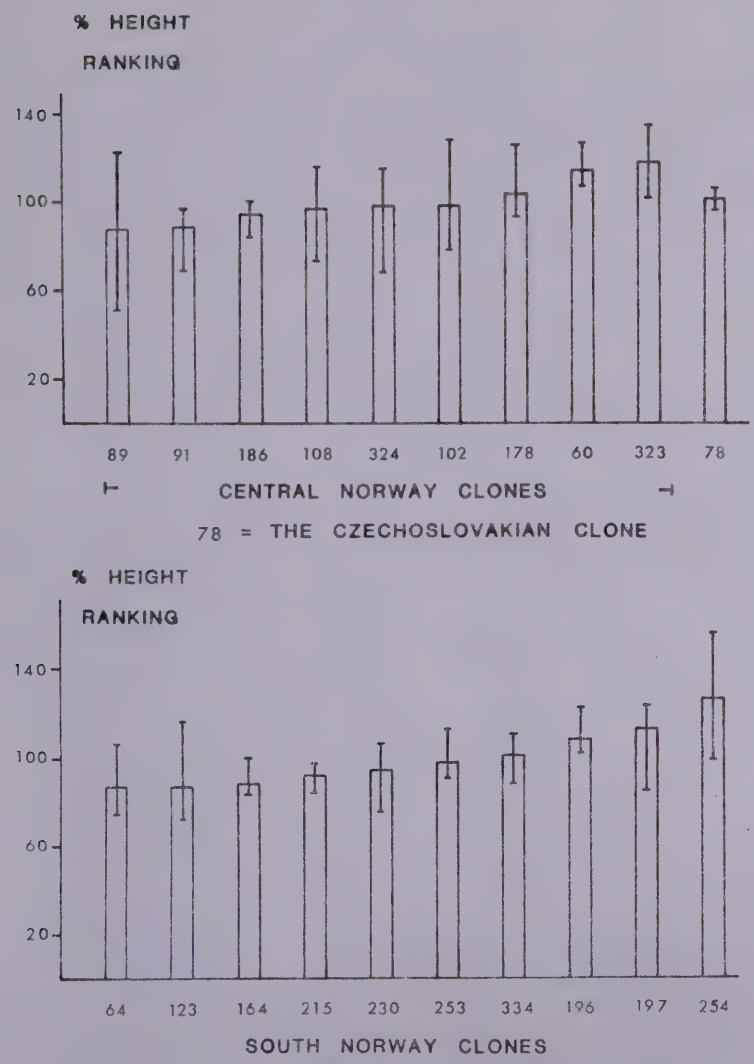

Fig. 6. The height ranking of the clones when the provenance mean is set equal to 100. Above: Central Norway clones, and one Czechoslovakaian clone. Below: Southern Norway clones. The central vertical line indicate smallest and largest ranking value within the six propagation cycles. The ranking of the Czechoslovakian clones is compared to the Southern Norway clones.
Høyderangeringen av klonene når proveniensmiddeltallet er satt lik 100. Øverst: Kloner fra Midt-Norge og en tjekkisk klon. Nederst: Kloner fra Syd-Norge. Den sentrale vertikale linjen angir den minste og største verdien innen de seks formeringsomgangene. Rangeringen av den tjekkiske klonen er sammenliknet med de sydnorske klonene.

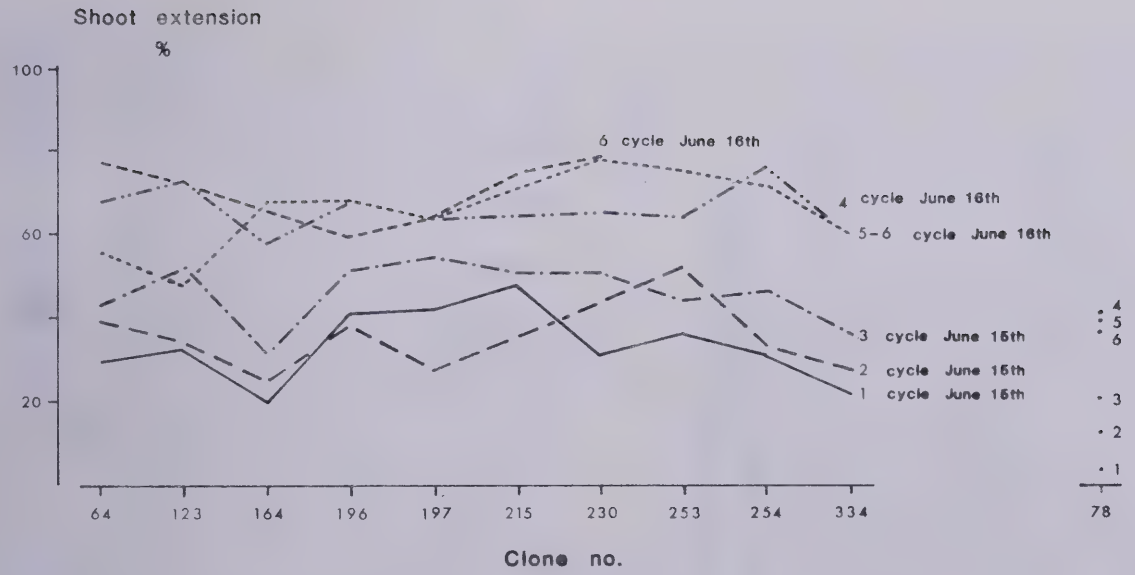

Fig. 7. The relative shoot extension for the six propagation cycles, measured on ten clones from Southern Norway, varied tremendously between cycles on June 15, and 16, 1981. Clones also behaved significantly different, but the error is large. Clone No. 78 from Mähren, Czechoslovakia to the right. Each dot indicates the cycle.
Den relative skuddstrekningen for de seks formeringsomgangene, målt på 10 kloner fra Syd-Norge, varierte meget mellom formeringsomrgangene den 15. og 16. juni 1981. Klonene oppførte seg også signifikant forskjellige, men forsøksfeilen er stor. Klon nummer 78 fra Mähren, Tsjekkoslovakia, er til høyre. Her viser hver prikk relative skuddlengder på de angitte datoer.

VII. Discussion

In spite of the fact that the ortets have been selected in a trial with «known breeding values» for the individual within the plots, family within the stand, and stand within the provenance, it is not possible to detect any relationship between the average height of the ramets and the corresponding predicted genetic value of the ortets. There are several possible explanations for this result. Firstly, the number of the selected individuals is few and the error in the heritability, especially for the selection within the plots might be quite large. On the other hand the family and stand heritabilities were estimated with more precision.

Another factor which also might have a strong influence is the low age of the ortets when selected. SKRØPPA (1981) analysed an older cutting trial with a total of 232 selections made when nine years old. The results showed that the correlation coefficient between clone mean height at age 20 and the ortet heights at different ages increased with ortet age up to 13—15 years. At age seven the response to individual tree selection was close to 0. Thereafter the response increased slowly up to ortet age 15 with an approximate value of $r = 0.2$. But if the family mean heights of the ortets were correlated with the mean of clones of the same families at age 20 in the clonal experiment, the response to selection improved. But still at age seven and nine the response was very low, but was close to $r = 0.5$ at age 11.

SKRØPPA concluded that if selection is going to be done for vegetative propagation, both family and individual tree performance must be utilized. The age, however, when such selections can be safely done (age 11 or more) seems to be too high to guarantee success in subsequent propagation cycles due to the ageing of the clones.

SKRØPPA's results, based on cuttings propagated when the ortets were nine years old, could still be confounded with c- effects and ageing. For the cuttings reported on here it has been interesting to observe a nearly complete lack of prolepsis. This is in clear contrast to what was observed on the same ortets at age seven. This could mean that free growth, which quite frequently creates large growth differences between individuals in a young seedling trial, has not had the same pronounced effect upon the growth of the aged clones (CANNELL and JOHNSTONE 1978). In other words the lack of free growth, which is considered to be a sign of ageing, may have changed the ranking of the clones relative to their performance as ortets. The most serious problem revealed by this study is, however, not the lack of correlation between ortets and ramets, but the low repeatability of clone performance from one propagation cycle to the next. This low repeatability is apparent for all the measured characteristics, and is shown as h^2 in Table 5. The repeatability, which for heights vary from 0.18 for the central Norwegian clones to 0.31 for those from Southern Norway, is much less than that obtained in the progeny trial with the seedlings. From these data for the southern Norwegian families within stands, and for one replicate the repeatability of plant height was 0.51. Clonal repeatabilities were also lower than seedling heritability for shoot length, flushing score and shoot extension (DIETRICHSON 1969). In the world literature poor repeatability between clonal repropagations has to

the authors knowledge only been reported on *Pinus radiata* (SHELBOURNE and THULIN 1974).

Reasons for the poor repeatability of clone performance in different propagation cycles may be:

(a) differences between the clones in root-growth
(b) different treatments during outplanting
(c) site differences

But such differences are likely to exist when propagation work of this kind is intended to be applied.

Another explanation for the poor repeatability of height growth among propagation cycles lies in plagiotropic growth. The clones from propagation cycle 1 in 1969 were straight-growing soon after out-planting in 1971. The clones in propagation cycle 2, 1970, turned out the same way as in cycle 1, but grew somewhat slower because of frost-heave. The material from the third propagation cycle in 1974 which was taken from 1969 ramets, and when the plants were approximately 0.5 metre tall, gave a high frequency of cuttings with plagiotropic growth (Photo 1), and it took three years before

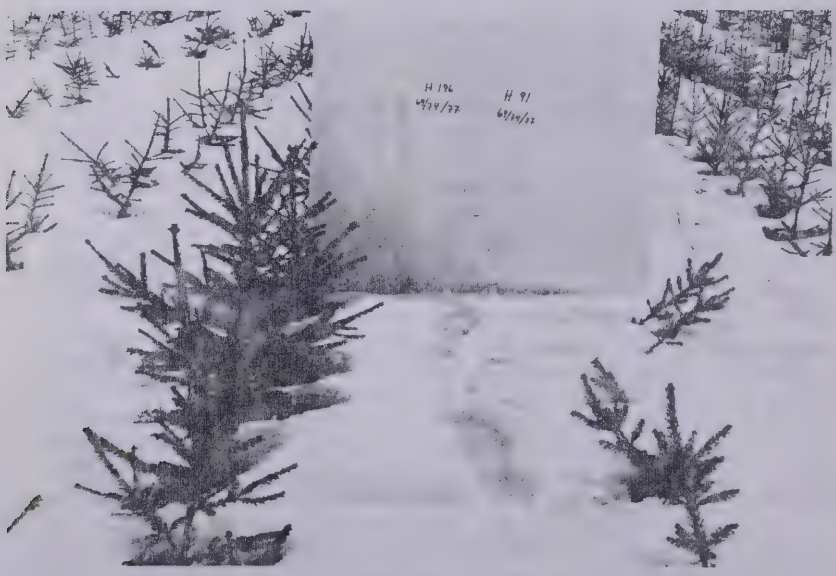

Photo 1. Plagiotropic growth on the cuttings became a problem already in the third propagation cycle. To the right, clone No. 91 from Central Norway with strong plagiotropic growth. To the left, clone No 196 from Southern Norway with normal growth. Photo February, 1981.
Plagiotropisk vekst hos stiklingene ble et problem allerede i tredje formeringsomgang. Klon nr. 91 til høyre er fra Midt-Norge (Ogndal 200 m.o.h.) og viser sterk plagiotropisk vekst. Klon nr. 196 til venstre er fra Syd-Norge (Trysil 400 m.o.h.) og viser normal vekst. Foto, februar 1981.

most of them were growing straight. Differences in plagiotropic growth between the clones were not predictable in spite of the fact that the cuttings were taken from a position, low in the crown, and of small trees.

In 1981 there appeared to be no differences between the clones in shoot length. It is reasonable to believe, if many kinds of environmental effects have reduced the clonal variability in height, that the shoot length on the well established plants should give larger clonal effects.

The highest repeatability for all the characteristics was for flushing score in the southern Norwegian clones. However the repeatability of 0.5 is still lower than the heritability of this trait with the seedlings. One cannot reject the hypothesis that differences in root-development and ageing also might create differences in the nutritional conditions in the plants. In this connection OGNER & TEIGEN (1980) reported large differences in the nutritional uptake between a sample of 7 clones from propagation cycle 3. Such differences might not only affect the height growth at different sites, but also the phenology of the cuttings.

The shoot extension study shows statistically significant differences only between the southern Norwegian clones. The calculations are based on measurements made om June 15. for propagation cycles 1, 2, and 3, and June 16. for the cycles 4, 5, and 6. In spite of the fact that the time lag between the measurements is only one day, the variance between the cycles σ^2_{pc} is 16 times as big as the variance between the clones σ^2_c. The most likely explanation for this large growth-retardation in cycles 1, 2, and 3, is that the soil temperature was lower in the plantations of these cycles caused partly by clay soil, partly by a low snow cover caused by high plant density, particularly at the site of cycles 1 and 2. For instance (Fig. 7) on June 15, clone 164 in propagation cycle 1 had extended 20 % of its shoot length, but in cycle 5, the same clone had extended 68 % the day after. This means a difference of 48 % between the two microsites and cycles. If the same comparison is made for clone 78, the Czechoslovakian one, cycle one shows 3.4 % and cycle five 39 % or a difference of 35.6 %.

The large growth retardation which has appeared for all clones in propagation cycle 1, 2, and 3, is without much doubt caused by the serve local site conditions which are of course confounded with propagation cycle. But only the Czechoslovakian clone No. 78 has shown up severe frost-damage and reduced growth (Photo 2). In this case selection of an individual of imported southern origin in a very good microclimate, and then planting of ramets of this same clone only a few hundred metres away under more severe conditions, had led to poor results.

Photo 2. Cuttings of clone No. 78 from Mähren, Czechoslovakia, suffered of frost damage several years, and the trees have grown poorly. The trees are indicated by arrows. Photo from propagation cycle No. 1, March 1982.
Stiklingene av klon nr. 78 fra Mähren, Tsjekkoslovakia, led av frostskader i flere år, og trærne vokste dårlig. Trærne er vist med piler. Bildet er fra formeringsomgang nr. 1, mars 1982.

VIII. Conclusions

This propagation trial, which was started when the original ortets were eight years old, has not given results favourable for a clonal forestry. The gain from selection of outstanding individuals within quite good families within the same provenance has been negligible. Because the number of plants were small, and the plants young, the result could have been expected, but nevertheless it is a demonstration of the ineffeciency of such juvenile selection as part of a programme of vegetative mass propagation by cuttings.

The most severe objection to propagation of eight-year-old seedlings, and later repropagation over successive generations of the same clones, seems to be the poor repeatability of ranking of clones in different propagation cycles. Different degrees of ageing, cyclophysis and topophysis (ROULUND 1979, OLESEN 1978), which cannot be controlled, make predictions of the growth potential for the different clones very difficult. Much the same results were obtained for growth rhythm characteristics i.e. flushing and shoot extension, and because of this it was decided not to mass propagate the material any further.

The material in this study does not provide any indication of results of propagating four-years-old seedlings, then repropagating every three to four years. In our opinion, mass propagation of any material should not be made operational before a satisfactory «gain» can be demonstrated. Equal or better growth than seedlings is one criterion of gain (see Roulund 1978, Sweet and Wells, 1974), low genotype — environment interaction is the second (Shelbourne 1974), and high stability over repropagation cycles is the third. All this criteria should be satisfied if clonal forestry is going to be introduced for Norway spruce.

IX. Summary

The purpose of this study was to examine the possibility of increasing the genetic gain by using good individuals from different provenances, good stands within provenances, and good families within stands.

Out of a total number of 336 clones that were propagated as cuttings in 1969, the 20 with the highest rooting ability were repropagated five more times from 1970 to 1977. Of the 20 clones, nine came from four stands in Central Norway, ten from six stands in Southern Norway (Table 1) and one from a Czechoslovakian stand i Mähren. The ortets of Norwegian origin were selected among the families that ranked first or second in mean height amongst the other families from their stand. At the same time the ortets were selected as good performers within their plot. The trial utilized a randomized complete block design with four replications, and plots of 16 plants at a spacing of 0.5 metre. The predicted genetic gain from selection of ortets has been based on variance components.

Based on variance components, heritabilities, and selection differentials, the genotypic value of each ortet was calculated as the sum of gains from the three stages of selection:

(1) the individual within the plot
(2) the family within the stand
(3) the stand within the provenance.

The genotypic values for the ortets have been correlated with clone mean values from the six propagation cycles. No statistically significant correlations could be detected for height, leading shoot length, and flushing state within each of the two Norwegian provenances. To check this results, the phenotypic values of the ortets were also correlated with the clone mean values, but the same poor result was still apparent.

The second part of the study concerned the repeatability of clonal differences between propagation cycles. The repeatability, based on one propagation cycle appears to be very low, and lower than was calculated for the same characteristics on a single plot basis in the seedling trial.

Utvalg av åtte år gamle granplanter i ett avkomforsøk og masseproduksjon av stiklinger

Formålet med denne undersøkelsen har vært å øke foredlingsframskrittet ved å velge fremragende enkeltplanter fra forskjellige provenienser, når disse samtidig er fra gode bestand og familier.

Av et totalt antall av 336 kloner, som var formert som stiklinger i 1969, ble de 20 med høyest rotsettingsevne formert fem ganger til fra 1970 til 1977. Av de 20 klonene kom ni fra fire bestand i Midt-Norge og ti fra seks bestand i Syd-Norge (Tabell 1) og en fra et tsjekkisk bestand i Mähren. Ortetene av norsk opprinnelse ble valgt blant familier som rangerte nr. en eller to i middelhøyde blant de andre familiene i samme bestand. Samtidig ble ortetene valgt fra gode fenotyper innen sin egen rute. De ulike familiene var fordelt på tilfeldig måte innen de fire gjentakene, og hver rute bestod av 16 planter. Det var anvendt en planteavstand på 0,5 meter. For å forutsi den genetiske gevinst ved utvalget av ortetene er det benyttet varianskomponenter.

Basert på varianskomponenter, arvbarhet og seleksjonsdifferensialene, er den genotypiske verdi av hver ortet beregnet som summen av gevinstene for de tre seleksjonstrinnene:

(1) Individet innen ruten
(2) Familien innen bestandet
(3) Bestandet innen proveniensen

De genotypiske verdiene for ortetene er blitt korrelert med klonenes middelverdier i de seks formeringsomgangene. Ingen statistiske signifikante korrelasjoner er påvist for høyde, toppskuddlengde, og skuddskyting innen hver av de to norske proveniensene. For å kontrollere dette er de fenotypiske verdiene for ortetene også korrelert med klonenes middelverdier, men det samme dårlige resultatet kom fram.

Den andre delen av undersøkelsen gjelder gjentakseffekten av klonforskjellene mellom formeringsomgangene. Gjentakseffekten, fra en formeringsomgang til den neste, viser seg å være meget lav, og lavere enn beregnet for de samme karakterene for et gjentak i forsøket med frøplantene.

Utvalg av planter, som er åtte år gamle, og deretter suksessiv vegetativ masseformering etter den fremgangsmåte som er benyttet her, har ikke gitt de positive resultater mange kanskje hadde ventet.

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